

Research Article

Evaluating the Performance of Potato Genotypes Across Diverse Climatic Conditions

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Abstract

Potato (*Solanum tuberosum* L.) is a globally important crop plant producing high yields of nutritionally valuable food in the form of tubers. Growing conditions across Pakistan are not uniform and it is important to dissect the genotype by environment interaction to identify the material suited to a particular environment. In this study, fifteen potato genotypes, namely FD49-28, FD3-10, FD1-8, SH-19, SH-90, SH-330, SH-80, SH-95, SH-216A, and SH-103, along with standard varieties SH-5, Cardinal, and Diamant, were evaluated for their adaptability across four different locations in Pakistan during the autumn season of 2019-20 and typical agronomic practices were performed and a number of parameters including tuber yield were assessed. Results for tuber grades indicated that the genotypes FD3-10, SH-5, and SH-216A demonstrated better performance. Furthermore, the genotypes FD8-1 and FD1-10 showed a higher level of tolerance to tuber diseases, indicating their potential for disease resistance in potato cultivation. Regarding tuber yield, SH-216A and FD49-28 were the top-performing genotypes, achieving significantly higher yields of 27 t/ha and 26.2 t/ha, respectively, when compared to the other varieties, including the standard ones. The material evaluated and information provided can be used to improve production methods for the industry.

Keywords

Emergence, Tuber, Location, Yield, Tolerance

1. Introduction

Potato is one of most important food crops of the world. It is a staple food commodity in many European countries. Processed potato products such as chips and crisps are commonly used as 'fast food' and 'snack food'. This crop has the potential to bridge the demand gap for food of increasing population and cereal production. Potatoes are an economical food since they provide a source of low-cost energy to the human diet. They are rich sources of starch and vitamins 'especially C, B & mineral'. Potato, which contains 75%

water contents is a tasty nutritive and highly digestible vegetable. It is free of cholesterol and contains some antioxidants which can protect human beings against cancer and heart diseases. It has the potential to lower blood pressure due to the presence of Kuko-amine.

Potato cultivation in the sub-continent is reported to have been introduced in the sixteenth century. In Pakistan, potatoes are cultivated on an area of 133.4 thousand hectares, with an estimated production of 2581.6 thousand tonnes. There has

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Received: 19 January 2024; **Accepted:** 18 February 2024; **Published:** 7 March 2024



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been a considerable increase in the area of about 31% and production by 47% during last ten years. However, the average yield remains the same i.e., around 13.4 tons/ha which of course is lower than available potential [1]. This is prospective area where efforts are needed for yield improvement. Genetic diversity in potato cultivars has been studied extensively for high yielding, diseases resistance and locally adapted potato cultivars. potato yields are affected by some major diseases, lack of improved, locally adapted potato cultivars, limited access to chemical fertilizers and a shortage of high-quality planting material [2]. It was concluded that phenotype was largely influenced by the locality (L) and the year of study (Y). Very significant cultivar (G) x locality (L), G x Y & G x L x Y interactions were also deduced. The highest number of large tubers and highly average yield were given by Kondor, Cosmos & Latona. Cultivar producing a lowest number of tubers such as Kondor had more plastic genotype and more stable yield than those producing many tubers the climatic conditions, however, favored very high tuber yields [3]. The highest yielding was the mid-late variety Dayana (67.33 t/ha), with a significant production of large-sized (>75mm) tubers (17.07%). Veronie which produced above average yield was characterized by a high percentage of commercial tubers (95.17%), which has uniformity and low frequency of defects [4]. strains 384640-3, 386029-18, 382021-9 and 382134-21 obtained good germination, best tuber grades, tuber yield, tolerance to rhizoctonia and cracking [5]. The standard variety Diamant, however having high specific gravity and dry matter content showed low germination, poor tuber grades and lower tuber yield [6]. Potato cultivars varied in percent germination and yield potential. Ten potato cultivars tested out of these, two cultivars, Eramis and Onway out yielded the others (46.9 and 54.7 t/ha). Coytella and Freonika strains suffer cracking more than the control whereas Costella was resistant to scab [7]. Tuber yield of the cultivars ranged 30 to 40 t/ha smaller tuber 6 to 7%, medium tuber 86 to 87% and large tuber 17 to 18%. The medium early maturing cultivars Arinda, Line-34, Cosmos, Marabel, and early maturing cultivars Binella are recommended for Erzurum ecological conditions [8]. The reported work in this paper is an effort to screen and identify the higher yield, better adaptive and better-quality potato strains.

2. Materials and Methods

2.1. Plant Material and Experimental Design

Fifteen potato genotypes, viz. FD 49-28, FD 3-10, FD 1-8, SH-5, SH-19, SH-90, SH-330, SH-80, SH-95, SH-216A, and SH-103, were used for the study. The experiment was conducted at four different locations, namely Vegetable Research Institute (VRI), Faisalabad, Farmer Field, Chiniot, Potato Research Station (PRS), Sialkot, and Punjab Seed Corporation (PSC), Sahiwal.

2.2. Sowing and Experimental Layout

The sowing of potato crop was done on four different dates: 19-10-2019, 23-10-2019, 28-10-2019, and 1-11-2019, corresponding to the different locations. Randomized Complete Block Design (RCBD) with three replications were used for the experiment. The plant-to-plant distance was maintained at 20 cm and row-to-row distance was set at 75 cm. Each plot size was 6 x 2.25 meters.

2.3. Crop Management

Typical agronomic practices and plant protection methods were applied to ensure optimal growth and development of the potato crop. To support healthy plant growth regular farming practices, including irrigation, fertilization, and pest control, were carried out.

2.4. Harvesting

When the potato crop was fully mature, the haulms (stems) were cut down and placed over the ridges. Harvesting was done on different dates for each location: 8-3-2020 for VRI, Fsd, 19-3-2020 for Farmer's Field Chiniot, 9-2-2020 for PRS, Sialkot and 26-2-2020 for PSC, Sahiwal.

2.5. Data Collection

Data on several parameters were recorded from plants, selected randomly from each replication. The following data were collected.

2.5.1. Emergence Percentage

The percentage of emerged plants from the total number of planted seeds was recorded for each genotype.

2.5.2. Tuber Diseases

For each genotype tuber diseases were assessed by calculating disease incidence.

2.5.3. Tuber Grades

The number of tubers categorized into three sizes (small, medium, and large) were recorded for each genotype.

2.5.4. Yield

For each genotype the total tuber yield per hectare was measured.

2.6. Statistical Analysis

The obtained data were subjected to statistical analysis using RCBD described by Steel and Torrie [9].

3. Results

3.1. Emergence

The data in (Table 1) shows that emergence of all the vari-

eties was normal in all the locations and was more than 80% on an average basis except strain SH-80 and standard variety SH-5 where the emergence was less than 80%. Maximum emergence percentage (94.9%) was recorded in strain FD 49-28 and minimum (75.6%) was recorded in variety SH-5.

Table 1. Emergence Percentage of Promising Strains at Different Locations.

Variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	Average
FD 49-28	97.4	98.9	93.3	90.0	94.9
SH-113	100	91.9	95.9	90.4	94.6
FD 8-1	95.6	94.4	95.6	89.6	93.8
SH-216A	98.1	90.4	94.4	73.7	89.2
Cardinal	87.8	93.3	94.1	78.5	88.4
FD 1-8	84.0	86.7	95.9	76.7	85.8
FD 1-10	80.0	91.1	95.2	75.9	85.6
SH-90	96.3	88.2	89.9	67.0	85.4
Diamant	82.2	86.7	90.7	80.7	85.1
FD 3-10	82.9	88.9	-	82.6	84.8
SH-330	98.5	81.5	93.3	64.1	84.4
SH-19	97.0	68.5	94.1	74.4	83.5
SH-95	85.6	85.9	93.3	57.0	80.5
SH-80	81.9	72.2	92.9	56.7	75.9
SH-5	66.3	78.2	93.0	64.8	75.6
LSD 5%	12.9	13.0	4.9	13.1	

3.2. Tuber Grades

Three classes of tuber grades based on their size i.e., <35mm (small), 35-55mm (medium) and >55mm (large) were studied.

3.2.1. Small Size Tubers (< 35mm)

Among the genotypes, the small size tuber differs significantly. The data presented in (Table 2) showed that due to frost and late blight disease there is a greater number of small size tubers. The maximum number of small tubers were produced by the variety Cardinal (25.1%) on average basis and minimum (10.4%) was recorded in FD 3-10.

Table 2. Percentage of tubers with <35mm size.

Variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	Average
Cardinal	10.0	15.0	65.0	10.3	25.1
FD-49-28	10.3	16.0	61.0	10.3	24.4
Diamant	9.7	13.7	59.0	10.7	23.3
SH-80	6.7	14.0	51.0	15.7	21.9
FD-1-10	8.0	8.3	58.6	7.7	20.7

Variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	Average
FD-8-1	9.0	6.7	56.0	9.0	20.2
FD-1-8	13.0	7.7	48.0	9.7	19.6
SH-95	11.7	10.0	45.0	8.7	18.9
SH-113	11.7	7.0	40.7	14.3	18.4
SH-19	9.0	9.3	47.7	6.7	18.2
SH-216A	8.3	11.7	41.0	8.0	17.3
SH-5	6.0	9.3	45.0	8.0	17.1
SH-330	9.3	8.7	42.0	7.0	16.8
SH-90	7.3	8.7	43.0	6.0	16.3
FD-3-10	8.0	13.3	-	10.0	10.4
LSD (0.5%)	4.1	5.5	8.1	4.1	

3.2.2. Medium Size Tubers (35-55mm)

The genotypes varied considerably for this grade (Table 3) in this category on an average higher number of tubers was found in strain FD3-10 (81.6%). While minimum number of tubers were recorded in genotypes FD 49-28 (65.9%).

Table 3. Percentage of Tubers with 35-55 mm size.

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	Average
FD-3-10	85.0	77.7	-	82.0	81.6
SH-90	85.7	80.0	35.0	80.3	70.3
SH-330	84.7	79.6	33.7	82.0	70.0
FD-1-8	77.7	80.6	37.7	80.6	69.4
SH-19	81.3	82.4	31.0	81.3	69.0
SH-216A	81.4	78.3	35.0	81.0	68.9
SH-113	82.3	79.7	34.3	78.7	68.8
SH-80	85.3	78.3	33.0	78.7	68.8
FD-8-1	84.3	81.3	26.7	83.0	68.8
SH-95	78.0	79.7	33.3	82.3	68.3
SH-5	84.3	80.0	27.7	79.0	67.8
Diamant	85.3	78.6	22.0	83.3	67.3
FD-1-10	81.0	80.0	24.7	82.6	67.1
Cardinal	83.0	79.0	21.7	82.7	66.6
FD-49-28	83.0	76.0	26.3	78.4	65.9
LSD (0.5%)	4.3	N.S	4.2	N.S	

3.2.3. Large Size Tubers (>55mm)

All genotypes vary considerably for this grade; maximum number of large size tubers (14.4%) was produced by the genotype SH-5. The minimum percentage of large size tuber (8.0%) was produced by the genotype FD3-10.

Table 4. Percentage of Tubers with >55 mm size.

Variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
SH-5	9.7	10.7	24.0	13.0	14.4
SH-216A	10.3	10.0	24.0	11.0	13.8
SH-90	7.0	11.3	22.0	13.7	13.5
SH-330	6.0	11.7	24.3	11.0	13.3
SH-113	6.0	13.3	25.0	7.0	12.8
SH-19	9.7	8.3	21.3	12.0	12.8
SH-95	10.3	10.3	19.7	9.0	12.3
FD-1-10	11.0	11.7	16.7	9.7	12.3
FD-1-8	9.3	11.7	14.3	9.7	11.3
FD-8-1	6.7	12.0	18.3	8.0	11.3
Diamant	5.0	7.7	22.3	6.0	10.3
FD-49-28	6.7	8.0	12.7	11.3	9.7
SH-80	8.0	7.7	16.0	6.3	9.5
Cardinal	7.0	6.0	3.3	7.0	8.3
FD-3-10	7.0	9.0	-	8.0	8.0
LSD (0.5%)	3.6	N.S	8.6	3.9	

3.3. Tuber Diseases

For tuber diseases, disease incidence was calculated by using the following formula:

$$\text{Disease incidence} = \frac{\text{No.of infected plants}}{\text{Total no.of observed plants}} \times 100$$

3.3.1. Scab

The incidence of scab was observed in all the strain at all the locations. Genotype FD49-28 was comparatively more susceptible due to high disease incidence (3.8%). The infection was lower in genotypes FD8-1 which was (1.5%).

Table 5. Disease Reaction (Scab%).

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
FD-8-1	1.3	1.3	2.3	1.0	1.5
SH-80	2.0	2.3	1.3	1.7	1.8
FD-1-10	1.3	1.7	3.3	1.0	1.8
FD-3-10	1.3	2.0		2.0	1.8
SH-216A	2.7	2.3	2.0	0.7	1.9
SH-330	1.7	2.0	2.0	1.7	1.9
SH-19	2.0	3.3	2.0	0.7	2.0
Cardinal	2.7	2.7	2.0	2.3	2.4
SH-95	2.3	3.0	2.0	3.0	2.6

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
SH-90	3.0	3.3	1.0	3.0	2.6
SH-5	1.7	2.3	3.7	3.0	2.6
Diamante	2.7	3.0	2.7	2.7	2.8
SH-113	4.0	3.0	3.0	2.3	3.1
FD-1-8	4.3	3.0	4.0	2.3	3.4
FD-49-28	5.3	4.7	4.0	1.3	3.8
LSD (0.5%)	N.S	1.4	N.S	1.0	

3.3.2. Rhizoctonia

Susceptibility was higher (12.7%) in genotypes FD3-10. Genotype SH-19 was tolerant as compared to others.

Table 6. Rhizoctonia %.

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
SH-19	1.0	2.0	-	2.0	1.7
SH-90	1.3	2.0	-	2.7	2.0
SH-216A	2.0	2.3	-	2.0	2.1
SH-330	2.7	1.7	-	2.0	2.1
FD-49-28	1.7	3.3	2.0	3.3	2.6
FD-1-10	2.3	3.7	-	2.0	2.7
SH-80	3.7	1.7	0.3	5.3	2.8
FD-8-1	7.3	0.7	-	1.3	3.1
SH-5	3.3	2.7	-	6.3	4.1
FD-1-8	3.3	6.0	-	7.0	5.4
SH-113	5.0	5.3	-	8.0	6.1
Cardinal	9.3	6.7	2.0	17.0	8.8
SH-95	9.3	6.7	-	17.7	11.2
Diamant	7.7	11.0	2.0	26.7	11.9
FD-3-10	9.7	9.3	-	19.0	12.7
LSD (0.5%)	3.3	3.2	1.4	5.5	

3.3.3. Skin Cracking

Skin cracking is an important parameter to test a genotype. Cracking ranges from 0.7% to 3.6% it was more (3.6%) in genotypes SH-330 than in Diamant and Cardinal (0.7%).

Table 7. Cracking %.

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
Diamant	0.7	0.3	-	1.0	0.7

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
FD-1-10	1.0	0.7	-	0.3	0.7
Cardinal	0.3	1.0	-	-	0.7
FD-3-10	1.3	0.7	-	0.3	0.8
FD-49-28	1.0	2.0	-	1.3	1.4
FD-8-1	1.3	3.0	-	0.3	1.5
SH-216A	3.0	0.7	-	0.7	1.5
SH-95	1.3	1.7	-	1.7	1.6
SH-80	2.3	2.0	-	2.0	2.1
SH-90	2.0	3.3	-	2.3	2.5
FD-1-8	1.7	3.7	-	2.7	2.7
SH-19	3.3	3.0	-	2.7	3.0
SH-113	4.3	4.0	-	1.7	3.3
SH-330	3.3	4.3	-	3.3	3.6
SH-5	5.0	5.0	-	6.0	5.3
LSD (0.5%)	2.6	1.9	-	1.3	

3.4. Tuber Yield

All the genotypes differ significantly in tuber yield at all the locations. Tuber yield was low on an overall basis due to frost, which reduced the potato production to some extent. Data in Table shows that on average basis the strain SH 216-A produced maximum tuber yield (27.0 t/ha) followed by FD 49-28 (26.2 t/ha), SH 113 (23.7 t/ha), FD 8-1 (23.0 t/ha). All these strains produced more yield than standards. The standard varieties Cardinal and Diamant produced 18.3 t/ha and 17.8 t/ha, tuber yield, respectively. Minimum tuber yield 14.6 t/ha on an average basis was recorded in strain SH-80.

Table 8. Tuber yield (t/ha) at different locations.

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
SH-216A	28.7	21.0	30.4	27.9	27.0
FD 49-28	35.1	24.0	17.3	28.4	26.2
SH -113	28.4	22.0	20.2	24.2	23.7
FD 8-1	25.4	27.2	17.8	21.7	23.0
SH-95	24.7	23.7	18.0	23.0	22.4
FD 3-10	24.7	17.8	-	23.0	21.8
FD 1-10	22.9	20.7	16.8	26.2	21.7
FD 1-8	26.2	19.3	19.3	19.8	21.2
SH-90	19.3	21.0	21.2	20.7	20.6
SH-19	17.8	13.1	28.4	19.0	19.6
SH-330	16.8	18.0	22.7	16.1	18.4
Cardinal	20.0	18.0	16.0	19.3	18.3
SH-5	13.8	18.8	28.1	12.1	18.2

variety	VRI, Fsd	PSC, Sahiwal	PRS, Sialkot	Farmer Chiniot	AV.
Diamant	12.8	22.7	15.0	20.5	17.8
SH-80	17.3	11.1	17.8	12.1	14.6
LSD 5%	4.1	7.7	2.7	5.9	

4. Discussion

The research aimed to investigate the performance of potato crops under different climatic conditions, focusing on emergence percentage, tuber size, yield, and tuber diseases. The findings revealed significant variations in these parameters across different potato genotypes and varieties, indicating the influence of both external and internal factors on potato crop performance. The emergence percentage of potato plants is a crucial factor that affects crop production and subsequent population dynamics, ultimately contributing to the final yield. The study reported an average maximum emergence percentage of 94.9% in the strain FD 49-28, while the minimum of 75.6% was recorded in the variety SH-5. These variations can be attributed to factors like tuber dormancy control, which played a key role in expressing the differences in emergence percentages [10]. These results are in line with Tariq [6]. Similar studies by Bugarcic et al. [3] and Abbasi et al. [10] reported emergence percentages of more than 80%, which aligns with the current findings because in current results emergence% is also more than 80%. Furthermore, previous research revealed that large-sized seed tubers tend to have a higher emergence rate compared to small-sized tubers. This can be attributed to larger tubers containing more stored reserve foods, providing an optimal supply of carbohydrates for emergence [11, 12]. These results emphasize the importance of selecting appropriate seed tuber sizes to maximize emergence percentage and subsequently improve crop production.

The study also examined the distribution of tuber sizes in three categories: small size tubers (<35mm), medium size tubers (35-55mm), and large size tubers (>55mm) maximum tuber size were found in medium size tuber (81.6%) while minimum tuber size was found in small size tuber (10.4%). Same results were reported by sadik Ebrahim et al. [12] which confirm our findings. Variation in marketable tuber size among the genotypes may be due to genetics. Besides genotypes, management practices, seed quality and agro-ecological condition of the experimental site also affect the weight and size of tubers [13]. The different genotypes and strains exhibited variations in the distribution of tuber sizes. Tuber size is an essential yield component of potato crops, contributing significantly to the overall tuber yield [14, 15]. The variations in marketable tuber size among genotypes can be attributed to genetic factors, management practices,

seed quality, and agro-ecological conditions [13].

The positive correlation between tuber size and yield, as reported in the study and supported by Yuan et al. [16] highlights the importance of selecting genotypes that consistently produce larger tubers for higher yield potential. It is crucial for potato farmers to consider not only the genotype but also the environmental conditions and management practices to optimize tuber size and yield.

Black scurf caused by *Rhizoctonia solani* in potato crop also observed under different climatic conditions. Higher disease incidence 12.7% was found in strain FD-3-10 while lowest disease incidence 1.7% was recorded in strain SH-19. Similar variations in disease incidence were also supported by J. W. Woodhall et al. [17]. who reported that the disease incidence of potato scurf disease ranges from 0.9 to 39.2 by using different varieties. Potato scab disease was also attacking potato crops observed under different climatic conditions. The incidence of scab disease was found to be higher in regions with higher potato cultivation and mono-cropping practices Kritzman et al. [18]. However, the use of new seed tubers for sowing every year was found to decrease disease incidence in certain regions Santos-Cervantes et al. [19]. Genotype FD49-28 exhibited higher susceptibility to the disease, whereas SH-19 displayed tolerance. cardinal and diamant varieties showed 5.67% disease incidence was reported by touria E. et al. [20]. which is statistically different from our findings because of high disease inoculum in that region. However, some researchers have also reported that disease incidence increases when infected seed tubers are planted Santos-Cervantes et al. [19].

Frost and low temperatures were observed to cause physiological disorders in potatoes, such as skin cracking. The variation in cracking percentages among genotypes might be attributed to differences in their susceptibility to frost and low temperatures.

Tuber yield is a complex trait affected by both genotype and environmental factors. The study reported variations in tuber yield among different genotypes, with SH 216-A genotype producing the highest yield of 27 t/ha and SH-80 producing the lowest yield of 7.6 t/ha. These results are consistent with previous research conducted in other regions Habtamu et al. [21]. reported a total tuber yield variation of 18.34 to 48.29, 26.71 to 43.50 and 17.70 to 56.52 t/ha⁻¹ at Haramaya, Arbarakete and Hirna, respectively in Eastern Ethiopia. Similar tuber yield variation results were reported on potato by different researchers in Ethiopia [22-24]. Luitel et al. [25] also

reported a marketable tuber yield variation of 7.6 to 27.0 tha⁻¹ and similar tuber yield variation were also reported on potato by different researchers [25, 26] which is in favor of our results. In addition to the genetic makeup of the varieties, differences in tuber size, plant spacing, and others could have contributed to the observed yield variations among varieties and environments [27].

5. Conclusions

In conclusion, this study sheds light on the performance of potato crops under diverse climatic conditions, emphasizing the significance of genotype selection, tuber size, and disease management for achieving optimal yields. The findings provide valuable insights for potato farmers and researchers to make informed decisions to enhance potato crop productivity under various environmental conditions. However, it is important to acknowledge the limitations of the study, such as the limited number of genotypes analyzed and the variations in environmental conditions across different regions. Further research on a larger scale and using a wider range of potato varieties would enhance the strength of the findings.

Abbreviations

VRI: Vegetable Research Institute, Faisalabad.
 PRS: Potato Research Station, Sialkot.
 PSC: Punjab Seed Corporation, Sahiwal.
 FSD: Faisalabad.
 RCDB: Randomized Complete Block Design.

Conflicts of Interest

The authors declare no conflicts of interest.

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